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WHEAT SCAB *and its* Control

A 90-acre field of Marquis wheat ruined by scab

WHEAT SCAB greatly reduces yields and lowers quality. The disease occurs in the Central States and eastward, chiefly on wheat, but also on other grains and grasses.

Scab is caused by a minute parasite, a fungus, which grows in the wheat plant in somewhat the same way that the wheat plant grows in the soil. This parasite destroys the parts of the wheat plant in which it grows.

The parasite is present in scabby seed, causing poor germination and the blighting and weakening of seedlings. Later it attacks the wheat heads, causing a blight which commonly is called scab.

This same parasite also attacks corn, and if wheat follows corn the old, diseased stalks are the chief source of wheat-scab infection.

Moist, warm weather during the flowering period favors the development of wheat scab.

To control the disease—

(1) Avoid sowing wheat after corn unless the cornstalks are removed and the stubble completely plowed under.

(2) Plow under all crop refuse and clean up the old straw and grasses along the fence rows and in near-by waste places.

(3) Use clean seed of adapted varieties. Seed should be thoroughly cleaned, graded, and treated.

(4) Sow wheat when the ground is cool, winter wheat on the latest safe date in the fall and spring wheat on the earliest safe date in the spring.

Contribution from the Bureau of Plant Industry

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WHEAT SCAB AND ITS CONTROL.[1]

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LOSSES CAUSED BY WHEAT SCAB.

SCAB, or Fusarium blight, is a disease of wheat, rye, barley, and oats, caused chiefly by a minute fungous parasite known by the Latin name *Gibberella saubinetii* (Mont.) Sacc. In 1919, in spring and winter wheat alone, this disease caused losses amounting to almost 80,000,000 bushels, and the quality of much more was greatly reduced. The disease not only attacks the heads, but is carried on the seed and infects the young seedling, causing thin stands or weakened seedlings. The disease also attacks corn, on which it does great damage as a rot-producing disease. It also lives over winter in the diseased cornstalks, and when wheat follows the corn an abundance of wheat scab results.

Losses from wheat scab depend greatly upon the weather conditions during and shortly after the wheat is in blossom. Where moist warm weather prevails during the time the wheat is in blossom local scab epidemics occur. Each year the total losses in the United States are rather heavy; and at irregular intervals, as in 1919, epidemics develop, which spread over the winter-wheat area and extend

[1] The investigations upon which this bulletin is based were conducted in cooperation with the Wisconsin Agricultural Experiment Station, Madison, Wis., the Indiana Agricultural Experiment Station, La Fayette, Ind., the Funk Bros. Seed Co., Bloomington, Ill., and the Illinois Agricultural Experiment Station, Urbana, Ill.

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northward into the spring-wheat area, causing immense losses. In addition to the enormous reduction in yield, much of the wheat that is thrashed is infected with scab and its quality greatly lowered.

Wheat infected with scab is shriveled, gray, or whitish in color, and light in weight (fig. 1). Such shriveled, starchy kernels are thoroughly penetrated by the parasites. Badly scabbed wheat weighs only 30 to 40 pounds to the bushel and either grades as No. 3 or No. 4 or is rejected. Figure 2 shows graphically the average number of pounds of good wheat, of scabbed wheat, of other shriveled wheat not infected with scab, and of broken wheat (due to thrashing) in a 60-pound average sample of Marquis wheat col-

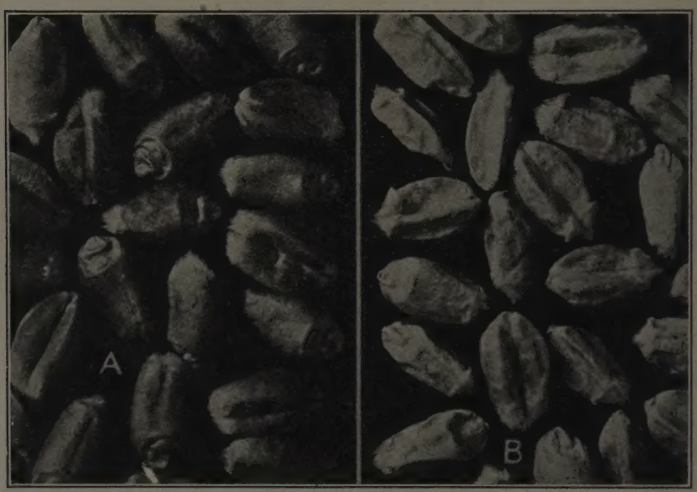

FIG. 1.—Healthy kernels (A) and scabbed kernels (B) of Marquis wheat. Scabbed kernels are badly shriveled, gray or whitish in color, light in weight, and contain an abundance of the parasite.

lected at elevators in Illinois in 1919. This sample was a mixture of a large number of small samples obtained at different elevators in central Illinois. The proportion and average condition of the kernels in each lot are shown in figure 3. In bulk the scabbed kernels occupy about the same space as the clean grain, but they weigh less. It is chiefly because of this that scabbed wheat runs so light. The wheat labeled "Shriveled" (fig. 3) represents kernels that may not be infected by the wheat-scab parasite, but have become shrunken on account of having their food supply cut off by attacks by scab or other diseases in other parts of the plant.

The clean kernels are plump, of good quality, and of high germination. The scabbed kernels are thoroughly infected with the parasite

(fig. 4) and when sown will produce seedling blight in the resulting crop. The shriveled and broken kernels are readily attacked by the scab fungus and by molds (fig. 4); hence, all these should be carefully separated from the good kernels in grain to be used for seed.

GEOGRAPHIC DISTRIBUTION.

The disease occurs throughout the world wherever wheat is grown, except in dry regions. In the United States it occurs in greater or less abundance each year from the Mississippi Valley eastward. During wet seasons the disease may extend westward into Kansas, Nebraska, and the Dakotas.

The distribution and relative abundance of the disease on both winter and spring wheat in 1919 are shown on the map (fig. 5).

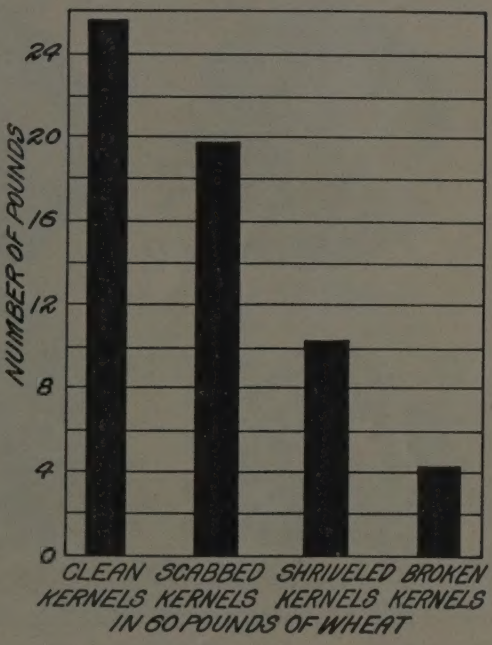

FIG. 2.—Diagram showing the proportion of clean kernels, scabbed kernels, other shriveled kernels, and broken kernels in a 60-pound sample of Marquis wheat, representing an average of samples collected at elevators in central Illinois in 1919.

GRAINS AND GRASSES ATTACKED.

The disease attacks wheat, rye, barley, spelt, and oats, as well as corn and various grasses, both wild species and weedy grasses, on farms. Among the grasses attacked are the following: Squirreltail grass (*Hordeum jubatum*), bluegrass (*Poa pratensis*), annual bluegrass (*Poa annua*), cheat (*Bromus secalinus*), and yellow foxtail (*Setaria glauca*).

DESCRIPTION OF THE DISEASE.

The disease develops on the wheat heads during flowering and filling, in the form of scab or head blight. It also occurs on the seedlings as a seedling blight.

HEAD BLIGHT.

The head blight becomes evident after flowering. One or more spikelets lose their green color, die, and turn light yellow. Frequently a pink or salmon color also is evident in parts of the blighted head, usually between some of the glumes and at the base of some of the spikelets. Either single spikelets or considerable portions of the head or the entire head may become blighted (fig. 6). The diseased parts, after bleaching to a light yellow, usually shrink and become dry. The kernels are destroyed or badly shrunken (fig. 1, B.) The

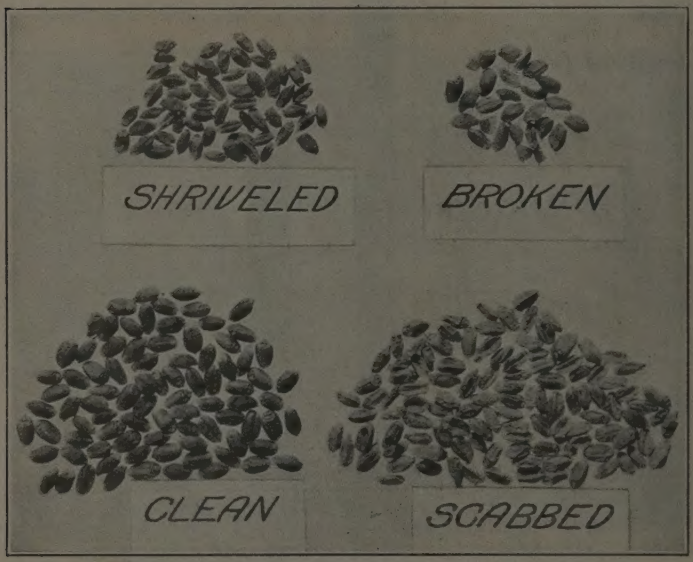

FIG. 3.—Approximate proportion of clean, scabbed, other shriveled, and broken kernels in a 60-pound sample of Marquis wheat, representing an average of samples collected at elevators in central Illinois in 1919.

kernels in the attacked portions of the infected heads not only become much shriveled but turn pale gray or whitish in color, or sometimes slightly pink, and become very light in weight.

When the disease spreads into the central stem of the head from attacked spikelets, the portion of the head above this point dies. The kernels above the infected point are shrunken because their food supply is cut off, although they are not infected (fig. 3, shriveled).

The parasite continues to develop throughout the season in the killed portions of the heads. The pink or salmon color mentioned

shows where this fungous growth develops along the edges of the glumes. At times this gives the whole infected part a pink color.

In the case of winter wheat, especially Turkey wheat, unless the weather is unusually dry the fungous parasite forms minute black bodies over the surface of the infected chaff and at the base of the diseased spikelets. These dark-blue or black winter-spore cases often become so numerous that they give a black color to the infected por-

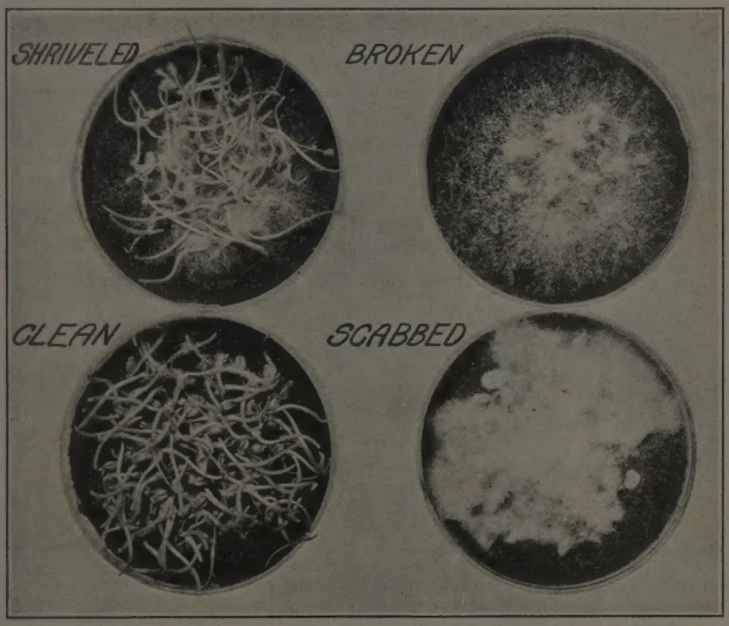

FIG. 4.—Results of germinating kernels from each of the four classes of wheat shown in figure 3. The clean grain germinated 99 per cent. Scabbed kernels become covered with the wheat-scab fungus, which causes the seedling blight when such kernels are sown. The other shriveled kernels give weak seedlings, which the scab parasite greatly weakens or kills entirely. The broken kernels are attacked by the common molds. All such kernels should be separated from the good grain before sowing.

tions of the head (fig. 7). The infected parts of the heads, including the kernels, become bleached and are slightly to greatly shrunken.

SEEDLING BLIGHT.

Seedling blight occurs either when scabbed kernels are used as seed or when poor seed is used on infested soil. The parasite attacks the seedling during germination and often kills it before it appears above ground. A poor stand results, which commonly is attributed to poor seed, unfavorable weather conditions, or other causes. Other

seedlings may come up and develop the first or often the second leaf before they are killed. Such seedlings show the characteristic symptoms of the disease (fig. 8). The parts above ground become yellow and wilt. When these plants are dug and the roots examined, the primary roots are found to be rotted off, while the lower portion of the stem and secondary roots are reddish brown in color and are rotted where the parasite has invaded them. In other seedlings only parts of the roots may be rotted. In such cases the plant develops weakly, fails to tiller, and finally sends up a single stem which bears a small head or none at all. All gradations of these blighted and

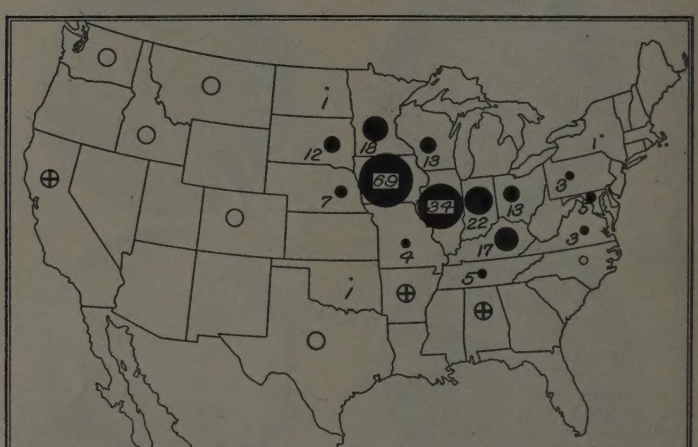

FIG. 5.—Outline map of the United States, showing the average percentage of wheat (both winter and spring varieties) infected with scab in 1919. The numerals and comparative size of the black circles represent the average percentage of infection. ⊕=A trace. ○=surveyed, but no scab found. Data obtained by the Offices of Cereal Investigations and the Plant-Disease Survey of the Bureau of Plant Industry.

stunted plants may occur. The seedling-blight type of injury, however, is rather inconspicuous and commonly overlooked.

CAUSE OF WHEAT SCAB.

The head blight and the seedling blight are caused by the same parasite. Countless numbers of minute plants live as parasites on or in other larger plants, in somewhat the same way as lice, ticks, mites, and worms live on and in horses, cattle, sheep, and other animals. As in the case of the animal parasites, these plant parasites do not make their own food as do green plants. They steal their food from their hosts, the plants on which they live, and weaken them accordingly. These plant parasites, mostly fungi (similar to molds), bacteria, etc., cause such disease as blights, scab, mildews, smuts, and rusts.

Wheat scab may be caused by three or more species of these minute parasites, but chiefly by the one which is known by its Latin name of *Gibberella saubinetii* (Mont.) Sacc. Two closely related species which cause the disease to a lesser extent are *Fusarium culmorum* variety *leteius* Sher. and *F. avenaceum* (Fr.) Sacc.

The chief wheat-scab parasite, therefore, is the fungus *Gibberella saubinetii*. In a series of investigations during the past two years, covering the wheat-growing sections of the Central and Eastern States, more than 95 per cent of the scab has been found to be caused by this parasite. Hereafter, in this bulletin, this organism will be spoken of as the wheat-scab fungus or parasite.

FIG. 6.—The scab, or blight, may kill only a single spikelet, or part of a head (center), or the entire head (right). Compare with the healthy head at the left.

This wheat-scab fungus is so minute that the use of a microscope is necessary to see it clearly. However, at times, especially in damp weather, masses of it can be seen as a pinkish moldy growth on the grain heads or straw or on old straw or cornstalks. This pinkish moldy growth contains the spores by means of which the fungus spreads during the summer ("summer spores"). It may be seen in

another stage as a rather inconspicuous black, rough growth. When this black growth is examined more closely, especially if a magnify-

FIG. 7.—The black winter-spore cases (perithecia) on a scabbed head of Turkey winter wheat. These contain the winter spores (ascospores). (Enlarged.)

ing glass is used, it will be seen that it consists of small spherical bodies or spore cases (figs. 7, 9, 10, and 11). It is really very dark blue in color rather than black. These spore cases contain the

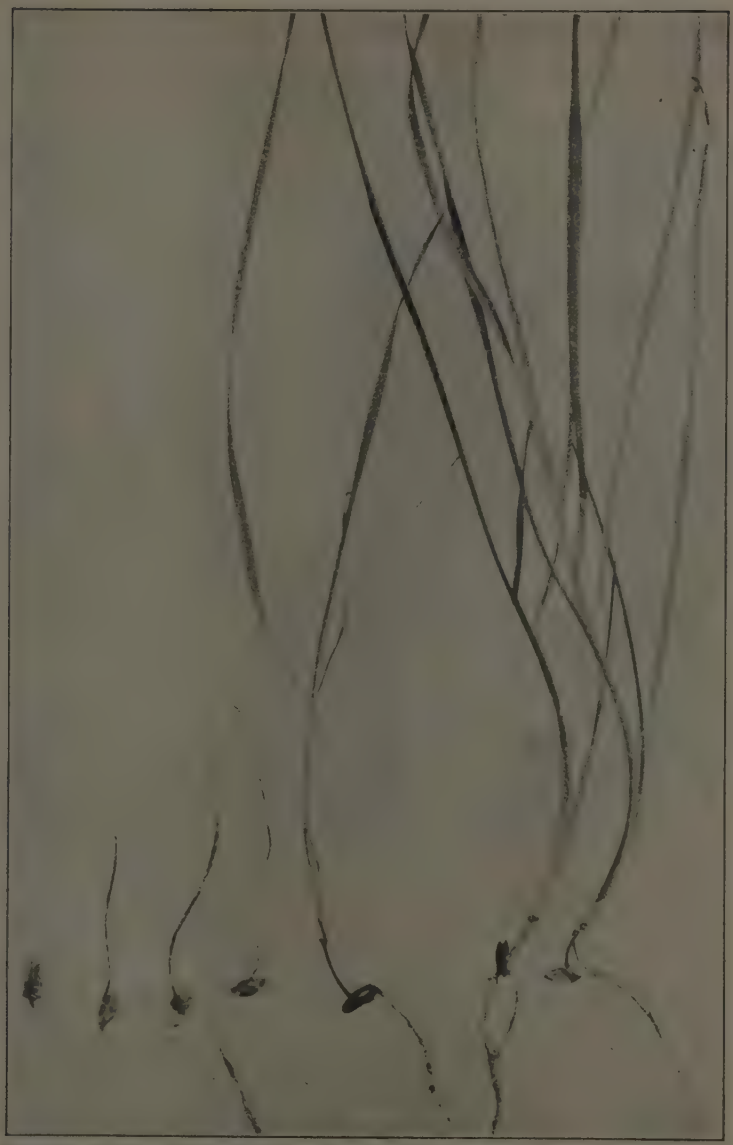

FIG. 8.—The seedling blight caused by the wheat-scab fungus. Some of the diseased wheat seedlings fail to push out of the soil (left), others come up but die in the first leaf stage, while others develop into weak plants (center). Normal seedlings, of the same age and from clean seed, are shown at the right. Clean and treat the seed in order to control this seedling blight.

spores ("seeds") of the fungus which carry the parasite over winter ("winter spores").

LIFE STORY OF THE PARASITE.

The life habits of the wheat-scab parasite are rather complex. As previously stated, it not only lives on various plants when they are growing, but it also lives on the straw, stalks, or other remains after the plants are dead. In fact, the fungus lives over winter very generally on this dead crop refuse as well as on and in infected seed.

FIG. 9.—Black winter-spore cases (perithecia) on wheat stubble left on the field after harvest. Unless all this material is plowed under the disease will spread to the next crop.

As pointed out previously, the parasite has two stages: (1) The summer-spore stage and (2) the winter-spore stage.

The winter-spore stage is produced on dead straw, cornstalks, or other dead plant parts, and serves to carry the parasite over winter. The tiny winter spores, produced in countless numbers inside of the black spore cases (figs. 7, 9, 10, and 11), are discharged during moist weather in the spring and early summer. If they fall on moist material of almost any kind, old straw, cornstalks, soil or manure, they start to grow and soon produce immense numbers of summer spores. The discharging winter spores may infect the wheat heads directly or the heads of other grains, but the greater part of this infection comes from the summer spores.

The parasite also overwinters in other ways: (1) In or on the surface of dead straw or cornstalks, in shiny masses of summer spores, and (2) in or on infected seed. New summer spores are produced from all of these sources as well as from the winter spores already mentioned. These fresh summer spores form the chief sources of infection for the scab or head blight.

The summer spores, being extremely small and light, are easily blown about by wind or any air currents. They lodge in the flowers of grain and start to grow. If sufficient moisture is present and weather conditions continue favorable the parasite penetrates and kills the invaded portions, producing the scab or head blight. Heads or parts of heads that are infected early in their development are blighted to such an extent that the attacked kernels are killed and become filled with the parasites. These kernels are much shrunken and very light. Other kernels, attacked later in their development, are not killed but carry the parasite in their outer coats. They may not be shrunken very much, if any, but usually are slightly grayish in color. Such kernels, when used for seed, usually will germinate. At the same time the parasite also will start growth and infect the developing seedling and neighboring seedlings, causing the seedling blight.

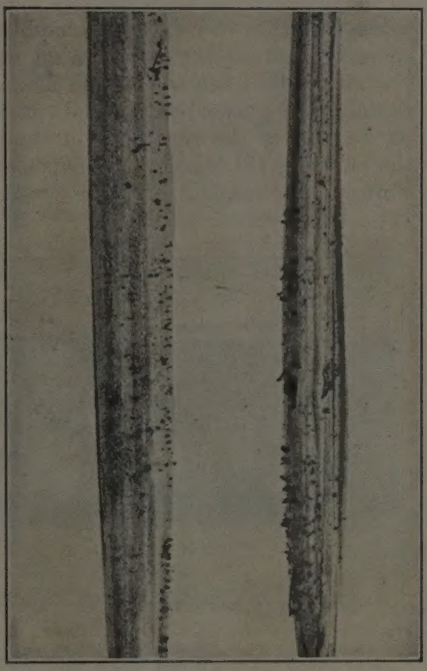

FIG. 10.—Black winter-spore cases (perithecia) on old grass stems and straw around a year-old straw stack. Plow under all grass and straw on waste places and clean up the fence line.

The fungus, developing on old straw, cornstalks, etc., in the fields, causes the scab (head blight), which results in infected kernels. The parasite in infected kernels causes the seedling blight.

WEATHER CONDITIONS FAVORING THE DISEASE.

Weather conditions have a marked influence on the development of the fungus, both of the head blight and of the seedling blight. The parasite grows best in warm, moist weather, just as corn grows best in warm weather.

CONDITIONS FAVORING THE HEAD BLIGHT.

Warm, rainy weather during flowering greatly favors the development of the head blight.

Spores of the parasite from old cornstalks or other crop refuse in the fields are carried to the wheat heads by the wind. Dry weather is unfavorable for the germination of these spores and the growth of the parasite, but warm, muggy weather, with heavy dews or quiet rains, furnishes very favorable conditions for the germination of the spores and subsequent growth in the wheat head. If these conditions prevail widely when wheat is in flower, a scab epidemic may spread rapidly over a whole region and cause immense losses. It is chiefly on account of the variations in the conditions—(1) abundance of the parasite, (2) stage of development of the wheat plant, and (3) warm, moist weather—that the severity of the head blight or scab varies from year to year.

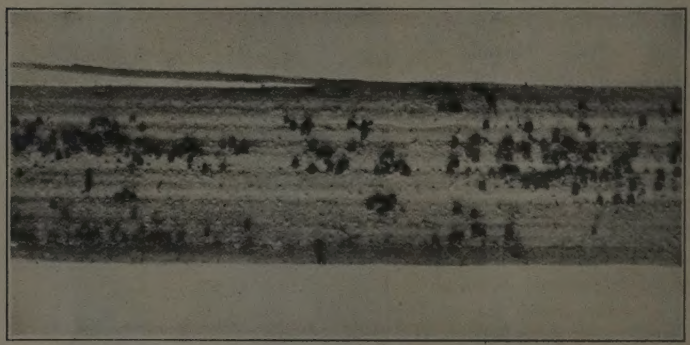

FIG. 11.—Black winter-spore cases (perithecia) on a piece of an old cornstalk taken from a wheat field. It is almost impossible to plow under all the cornstalks, and therefore wheat should not follow corn where some other rotation can be used. Oats or some crop not badly attacked by scab may follow corn safely.

CONDITIONS FAVORING SEEDLING BLIGHT.

The seedling blight develops chiefly from the scabbed kernels sown with the seed. A warm, comparatively dry soil favors the development of the seedling blight of wheat. If wheat is sown late in the fall or early in the spring when the soil is moist and cool, with a soil temperature of about 40° F., these conditions favor the development of vigorous stocky seedlings which resist the parasite. Under these conditions even scabbed kernels may produce fair plants.

CONTROL MEASURES.

Wheat scab is difficult to control completely. However, the losses caused by it can be greatly reduced. Rotation of crops; the use of well-prepared clean land, adapted varieties, and high-grade cleaned and treated seed; and sowing in a cool soil will greatly reduce the losses from this disease. All of these means are practicable and can be applied under farm conditions.

ROTATIONS.

Investigations conducted during the past three years have shown that wheat scab (head blight) usually is much more severe where wheat follows corn or wheat. In a number of cases the evidence has been very striking. In one case where wheat followed corn there was an average of 40 per cent of scab in contrast with an average of only 2 per cent in a near-by field of the same variety of wheat which followed oats. These percentages represent averages from a large number of counts from various parts of the two fields. In the first case, corn had been the preceding crop and a considerable number of the old stalks remained on the surface, while in the second case oats had been the preceding crop and the soil surface was clean.

In planning rotations, therefore, especially in sections where wheat scab occurs, it is best to avoid the risks taken by sowing wheat after either corn or wheat unless all old stalks or straw are removed or completely plowed under. As it is practically impossible to plow under and cover large cornstalks perfectly (fig. 12), it is better to follow corn with some crop not attacked by scab and then follow that with wheat, if this can be done.

CLEAN LAND, WELL PREPARED.

To control scab or the head blight, the old stalks of corn and straw of grains and grasses in the field and adjoining areas should be removed or carefully plowed under. Unless this is done the wheat-scab parasite lives over winter on such material and is ready to attack the wheat crop that follows. To reduce the injury from seedling blight, the soil should be in a good physical condition and a good seed bed prepared.

GOOD SEED, CLEANED AND TREATED.

To control wheat scab it is important to give careful attention to the proper selection and treatment of the seed to be sown. The varieties best adapted to the section, and, if obtainable, seed free from scabbed kernels should be used. If it is necessary to use wheat which has scabbed kernels in it, the grain should be put through a fanning mill with a heavy wind blast to blow out all of the scabbed kernels and shriveled grain. The importance of this will be seen by referring to figures 3 and 4. The kernels represented in the piles labeled "Scabbed" and "Broken" (fig. 3) usually are removed by fanning, leaving grain like that labeled "Clean." When such seeds are sown, the clean grain germinates almost perfectly if treated by the formaldehyde or modified hot-water method. These treatments reduce injury from the slight scab infections in kernels too plump to be removed by the fanning mill and also kill spores on the outside of the seeds. If carefully selected, graded, and treated seed is sown in a well-prepared fertile soil at the proper time sturdy seedlings will result. Strong well-rooted wheat plants will stand more unfavorable conditions and develop faster and better than those weakened by disease.

SOWING IN COOL SOIL.

Investigations have shown definitely that the wheat-scab parasite is a warm-weather fungus. It grows best when the air and soil temperatures are about 70° to 84° F. On the other hand, wheat seedlings grow best when the soil is cool. Wheat seedlings develop into stocky, healthy plants with a large well-developed root system when the temperature of the soil is about 40° to 60° F. At these

FIG. 12.—Cornstalks on a field of winter wheat. The cornstalks were broken down with a drag, after which the field was disked both ways and then plowed. Enough diseased stalks remain on the surface to carry scab to the entire wheat crop if weather conditions are favorable for the development of scab during the period when the wheat is in blossom.

temperatures the wheat seedlings are not easily attacked by the wheat-scab parasite.

Favorable soil temperatures are obtained by sowing winter wheat at the latest safe date in the fall and spring wheat at the earliest safe date in the spring. These low soil temperatures help to make a good stand of deeply rooted, vigorous wheat seedlings free from seedling blight. Such plants develop rapidly and mature early.

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